Surface Toughening – An industrial Approach to increase the Robustness of pure adhesive Joints with film adhesives

1st IAA2020

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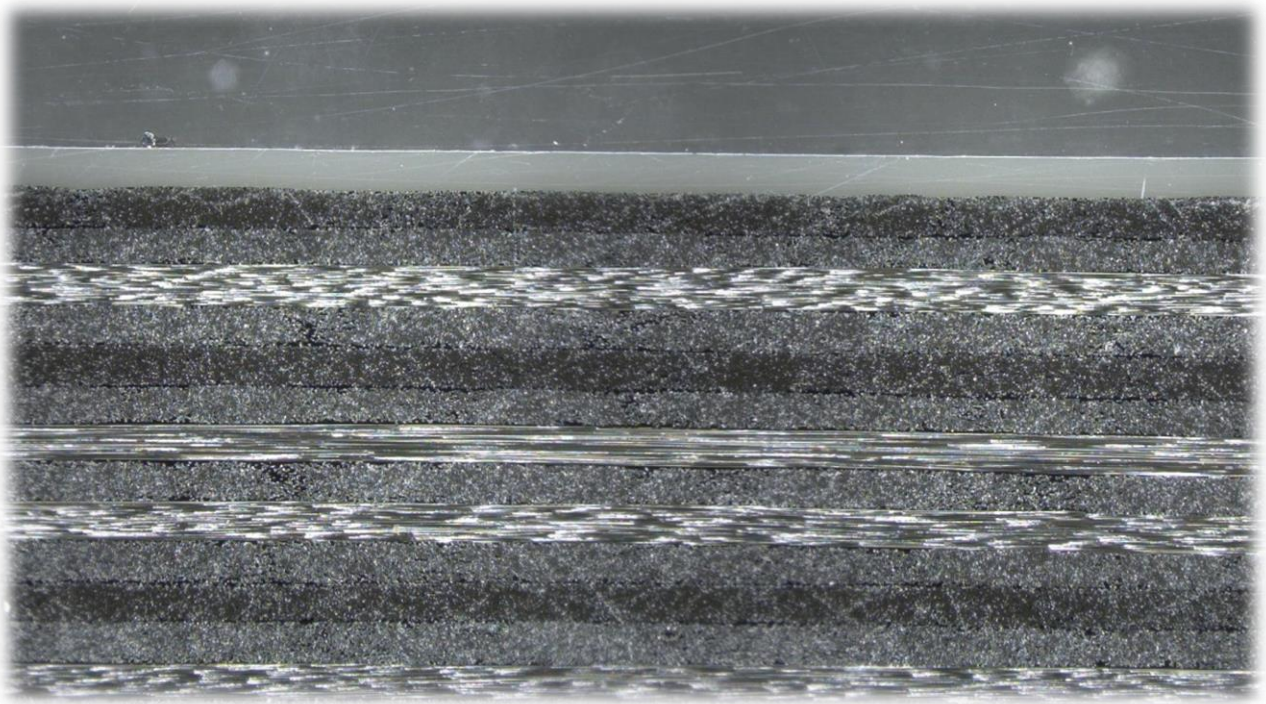
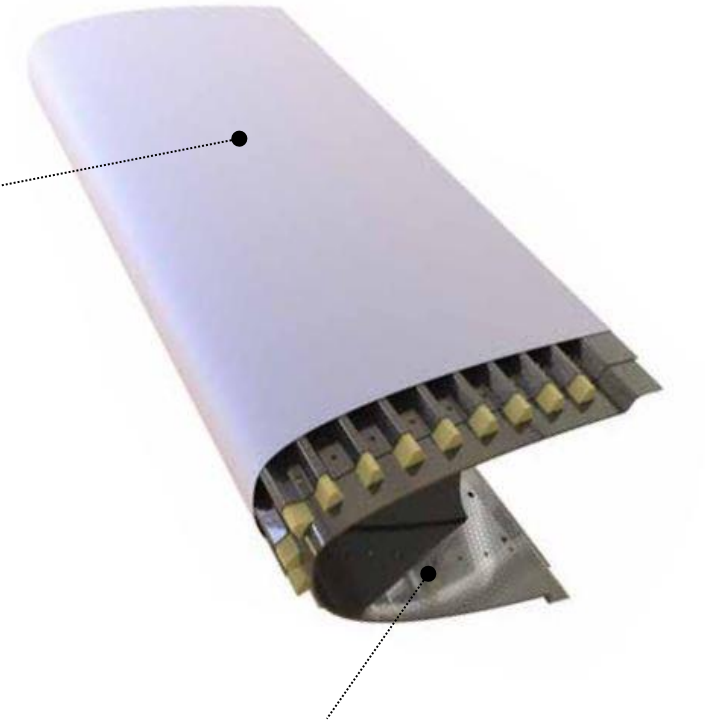
Overview

- Introduction & Motivation
- Surface Toughening
- Benefit for Joint Strength
- Benefit for Fatigue Strength
- Manufacturing and Results
- Conclusions and Outlook



Introduction to the Background

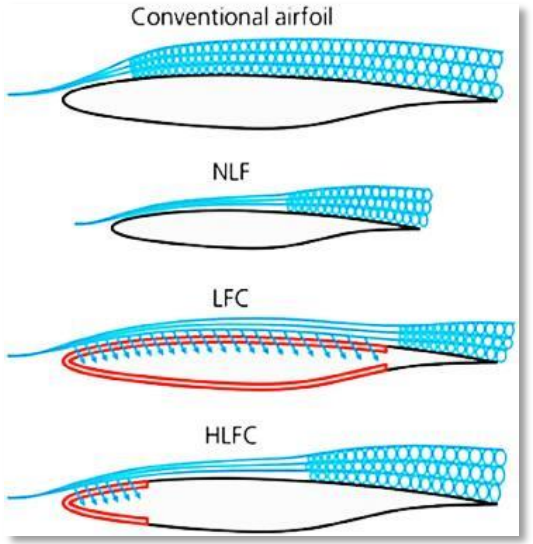
Horizon 2020 Project: Manufacturing of a HLFC-Leading Edge Demonstrator for A350 HTP



Where is the POI?

Bonding!

Horizontal Tail-Plane
Leading Edge (A320)

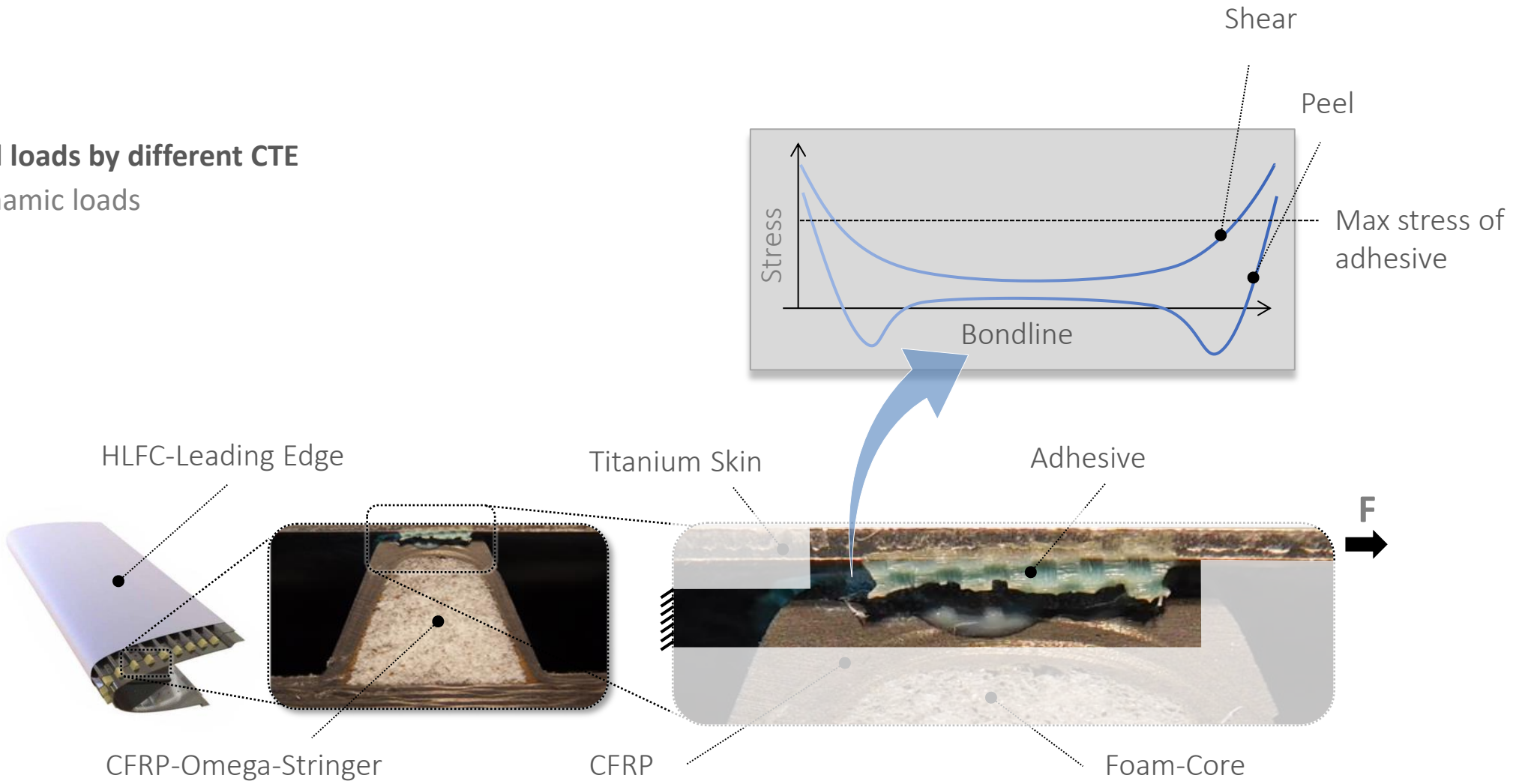


Hybrid Laminar Flow
Control [1]

Motivation for Surface Toughening

Loads:

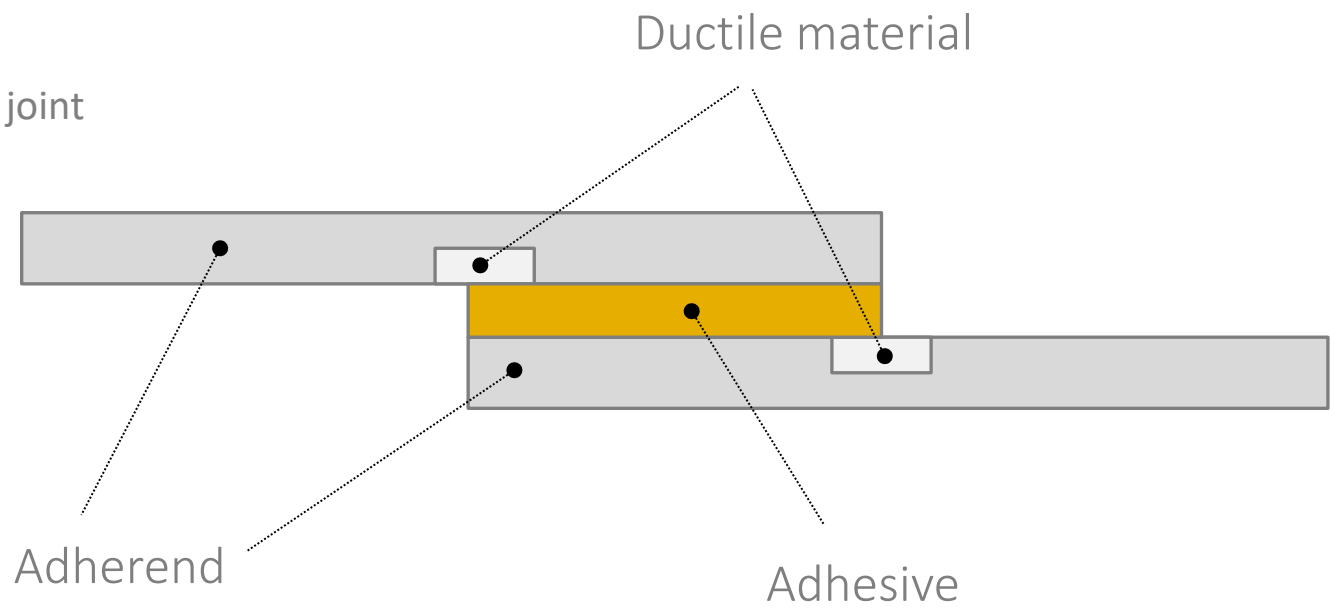
- **Thermal loads by different CTE**
- Aerodynamic loads
- Impacts



Surface Toughening (ST)

Ductile material is implemented into the surface of adherends

- ➡ homogeneous load transfer in joint
- ➡ load rearrangement to the middle of joint
- ➡ decreasing of stress peaks
- ➡ increase in joint-strength

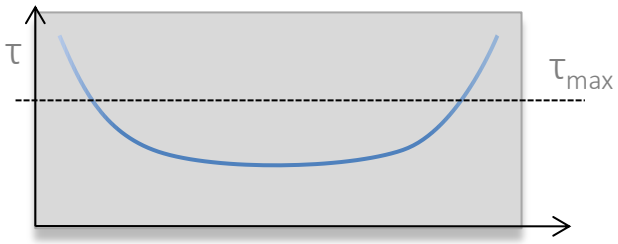


Benefit for Joint Strength (SLS)

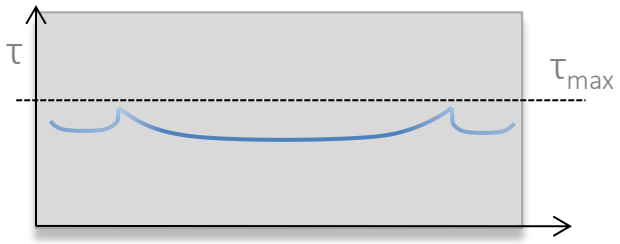
Requirements for ST:

$E_{Adherend} >> E_{Adhesive} > E_{ST}$

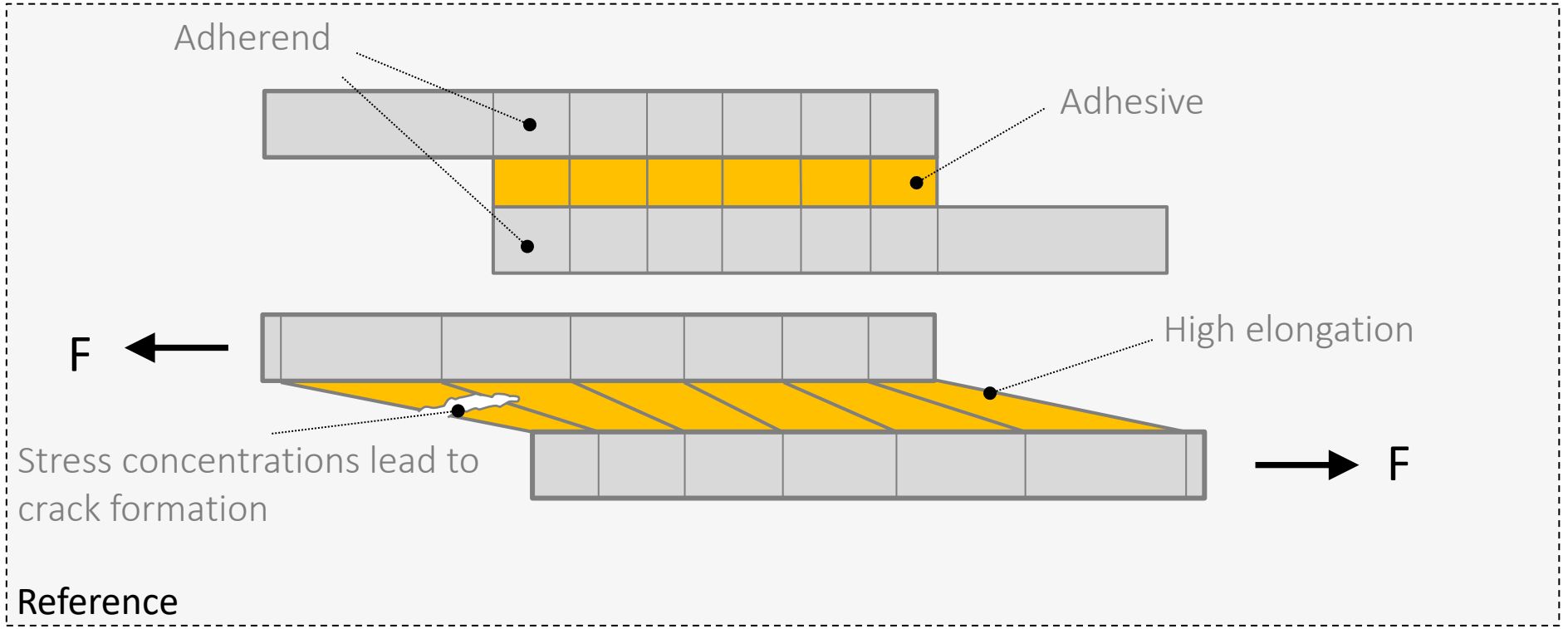
$\varepsilon_{br,\ ST} >> \varepsilon_{br,\ Adhesive}$



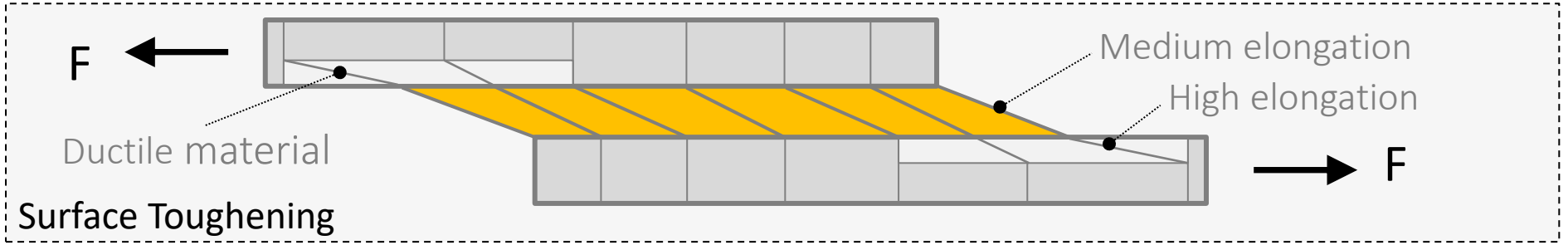
Bondline



Bondline



Reference



Surface Toughening

Material properties used in the Tests

Adherend:

Hexcel HexPly® 8552 IM7 Laminate

$[0/+45/90/-45/0/+45/90/-45]_S$,16 ply, 2mm

Young's Modulus [MPa]	65020	Curing at 180°C
Poisson's ratio:	0.31	

Requirements for ST:

$E_{Adherend} >> E_{Adhesive} > E_{ST}$

$\varepsilon_{br,\,ST} >> \varepsilon_{br,\,Adhesive}$

Adhesive [2],[3]:

Hysol® EA 9695 0.05 NW AERO

Young's Modulus [MPa]	2576.8	
Poisson's ratio:	0.43	
Tensile strength [MPa]	59.2	Curing at 130°C
Global elongation at break [%]	**3**	
Tensile Yield strength [MPa]	46.78	
Shear yield strength [MPa]	32.78	
Shear failure strength [MPa]	51.94	

Ductile material [2],[4]:

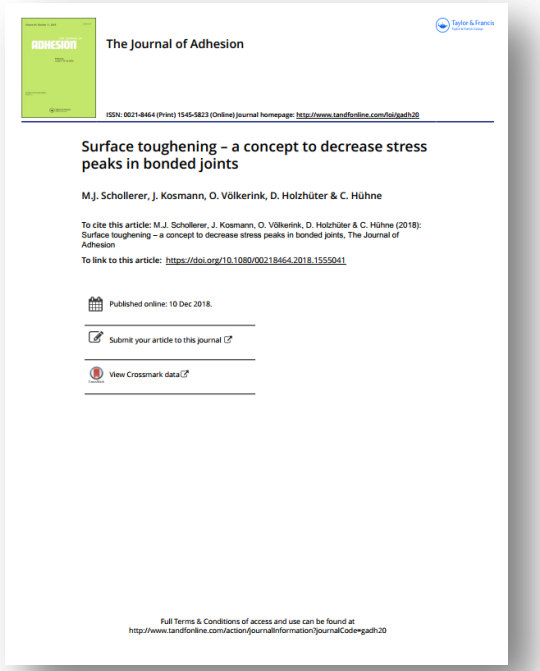
Kynar® 740, PVDF

Young's Modulus [MPa]	1716.1	
Poisson's ratio:	0.46	
Tensile strength [MPa]	51.5	Melting at 168°C
Global elongation at yield [%]	6.1	
Global elongation at break [%]	**35**	
Tensile Yield strength [MPa]	50.7	

Benefit for Joint Strength

Surface Toughening

- Increase in joint strength up to 84% (SLS ASTM D 5868)
- Increase in strength depends on geometry of ST
- Increase in strength higher than without ST
- Manufacturing and testing details →
- **No crack growth with ST**



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Surface toughening – a concept to decrease stress peaks in bonded joints

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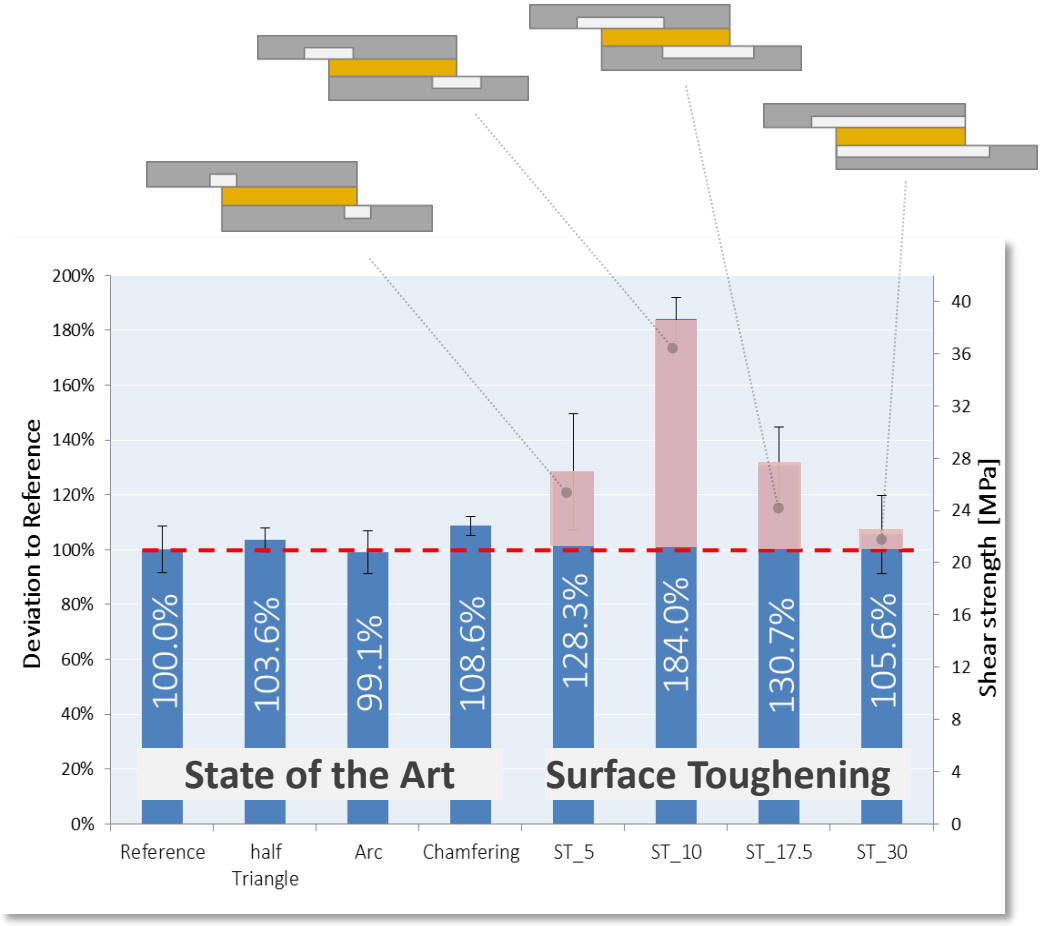
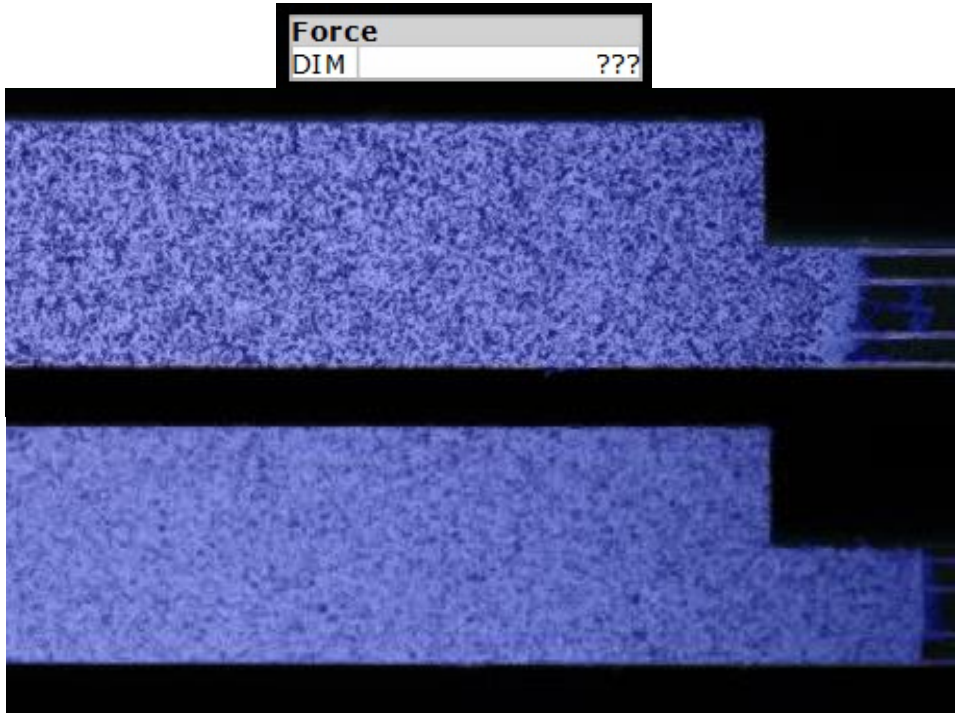


Results of SLS-tests

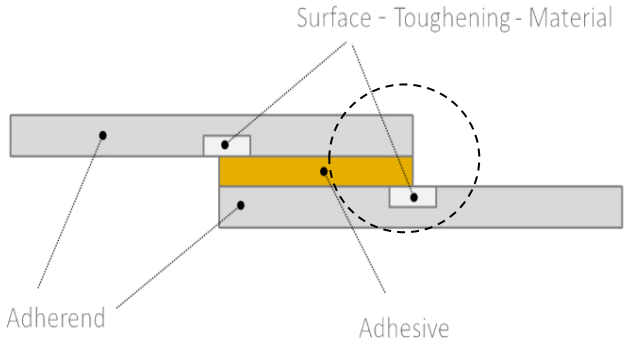
Difference in Failure

without
Surface Toughening

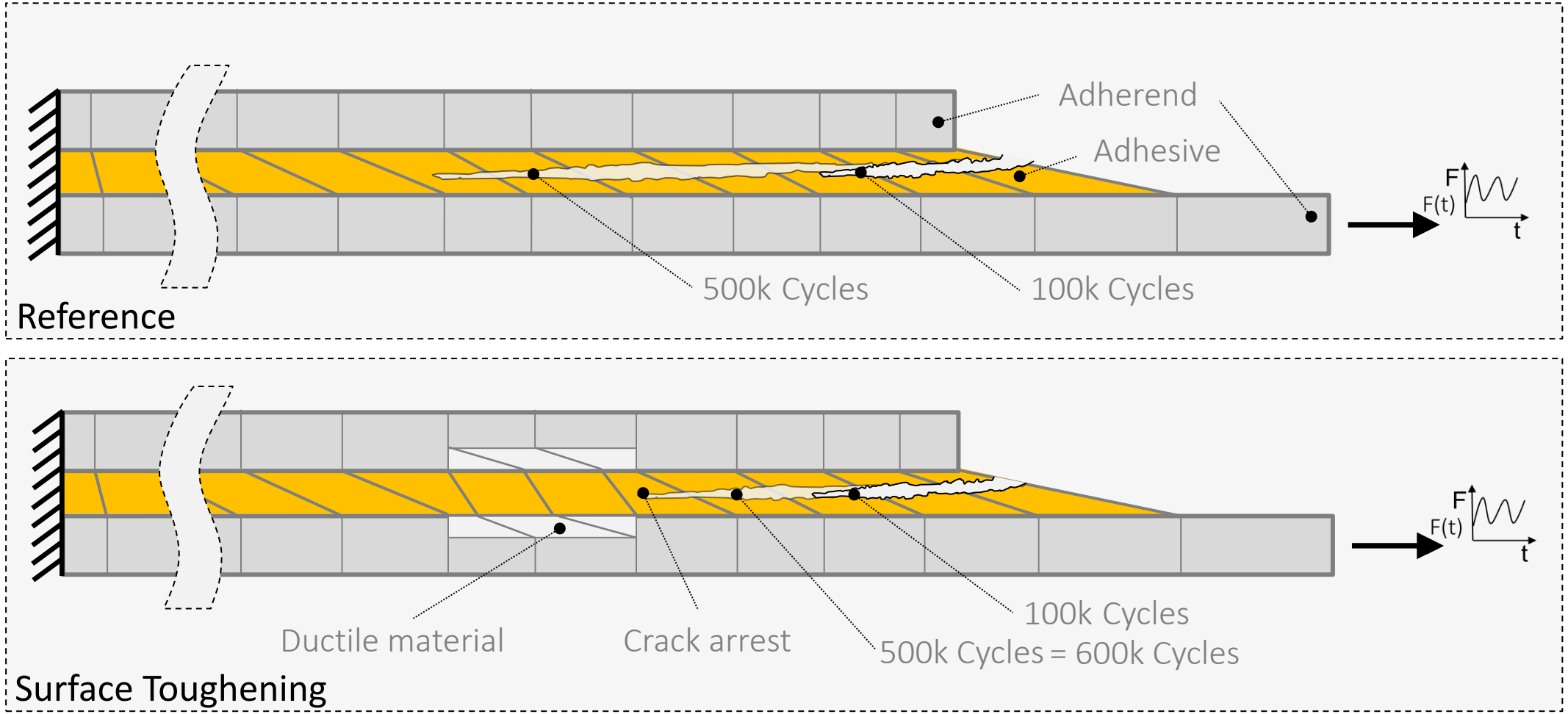
with
Surface Toughening



Video of static failure of SLS-specimen



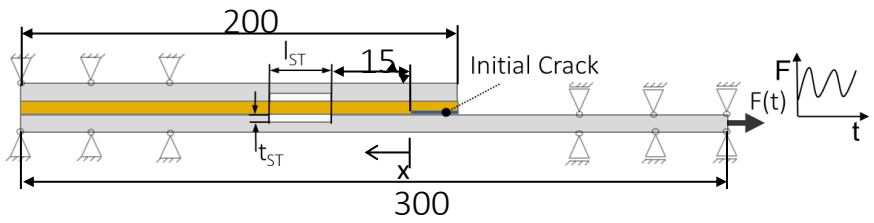
Benefit for Fatigue Strength (CLS)

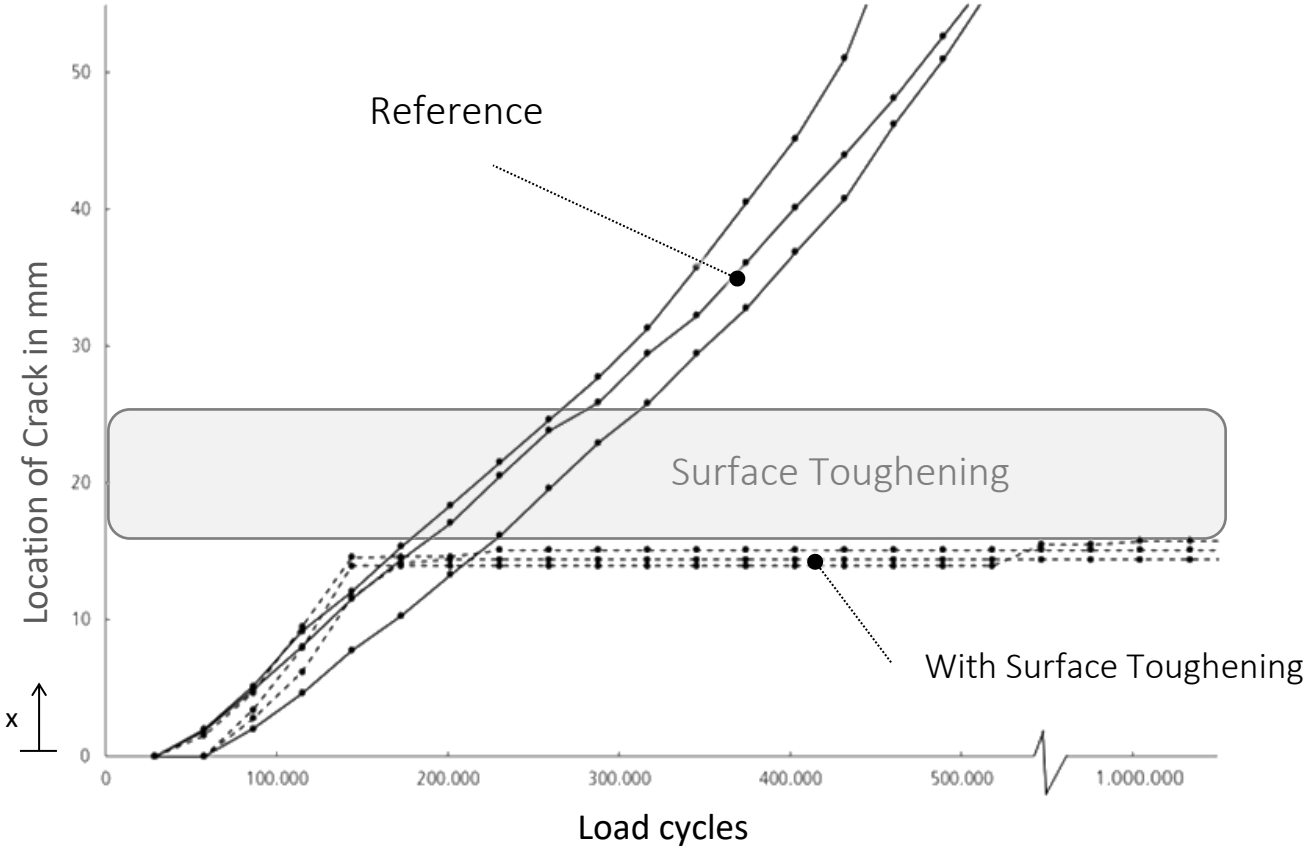


Benefit for Fatigue Strength

Surface Toughening

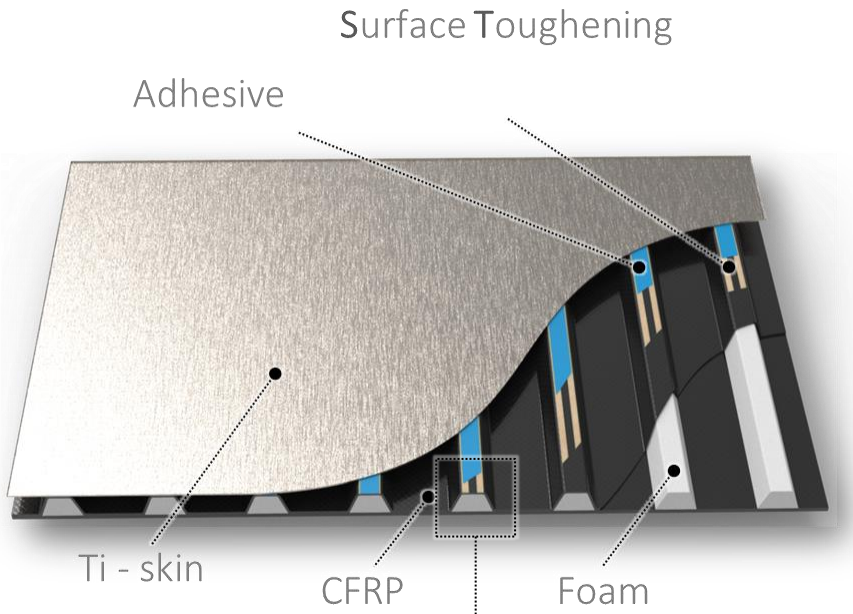
- Tested on Cracked lap shear specimens
- Crack arrest up to 3000µm/mm tested (9,28kN)
- 8Hz, 25,4mm width
- t_{ST}=0.1mm, l_{ST}=10mm
- Tests are still ongoing

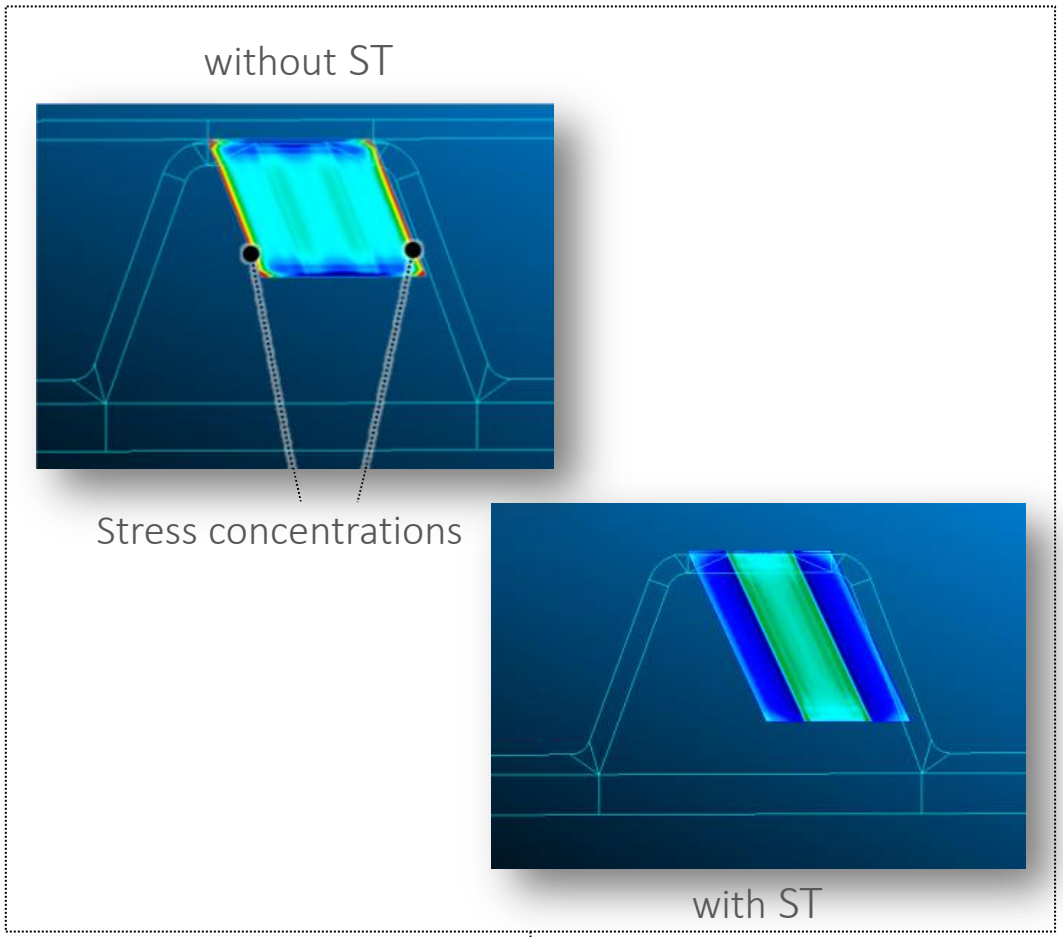


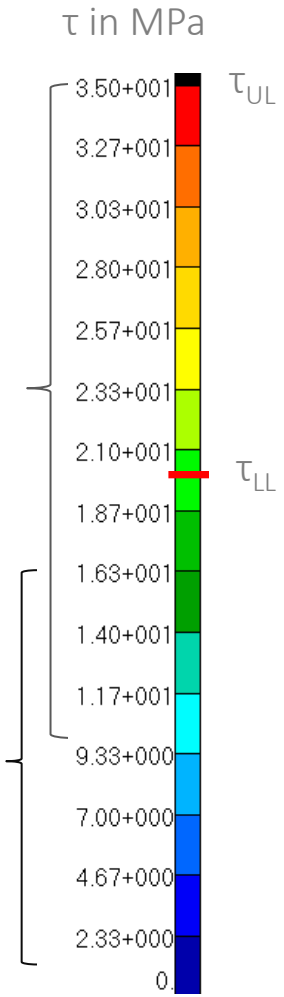


Surface Toughening in a Small Scale Demonstrator

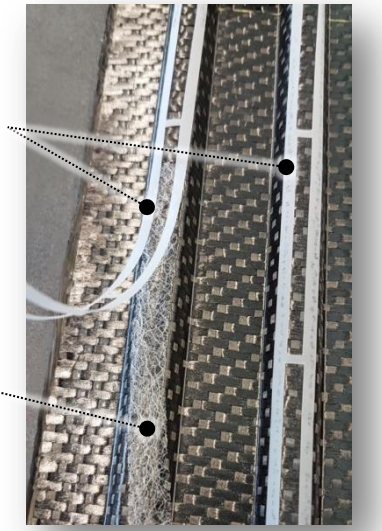
- Flat small scale demonstrator
- FEA analysis of bondline shear stress
- Cooldown from 120°C to 23°C

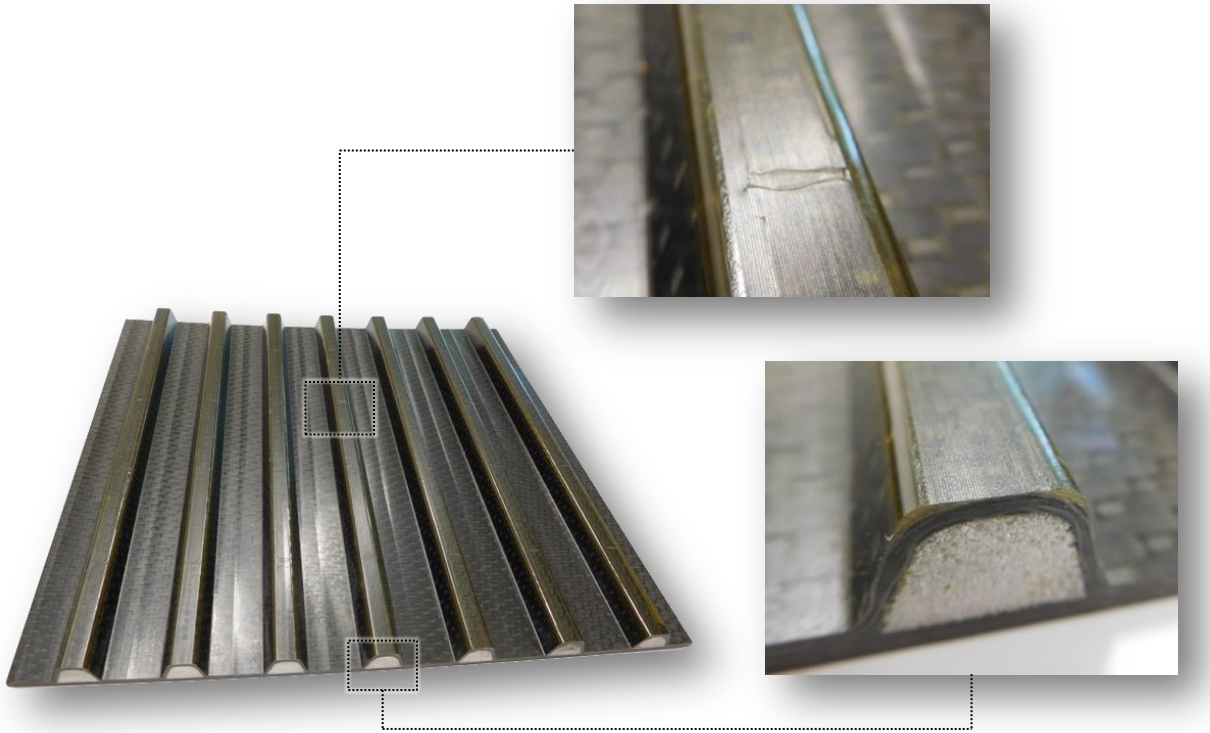






Manufacturing of a Small Scale Demonstrator





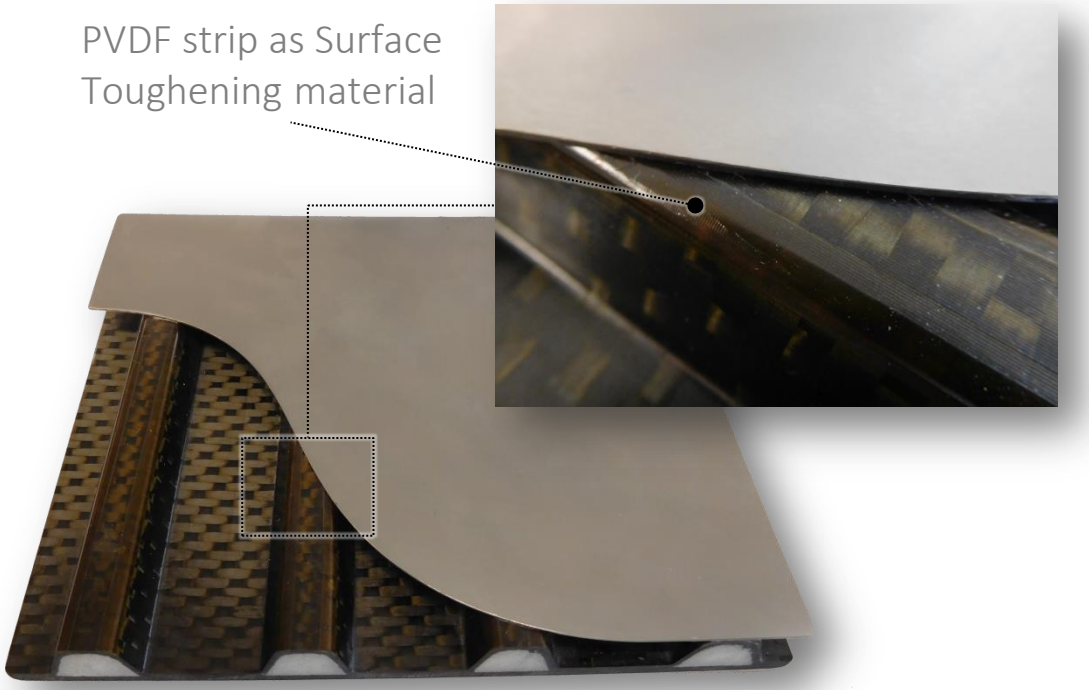
Preforming of G0926 fibers
- 100°C, 1bar
- Flat structure

Application of PVDF
- Usage of binder fleece for fixation
- Melting by soldering iron

Infusion with RTM6
- 180°C cure of resin
- Smooth surface
- No air inclusion

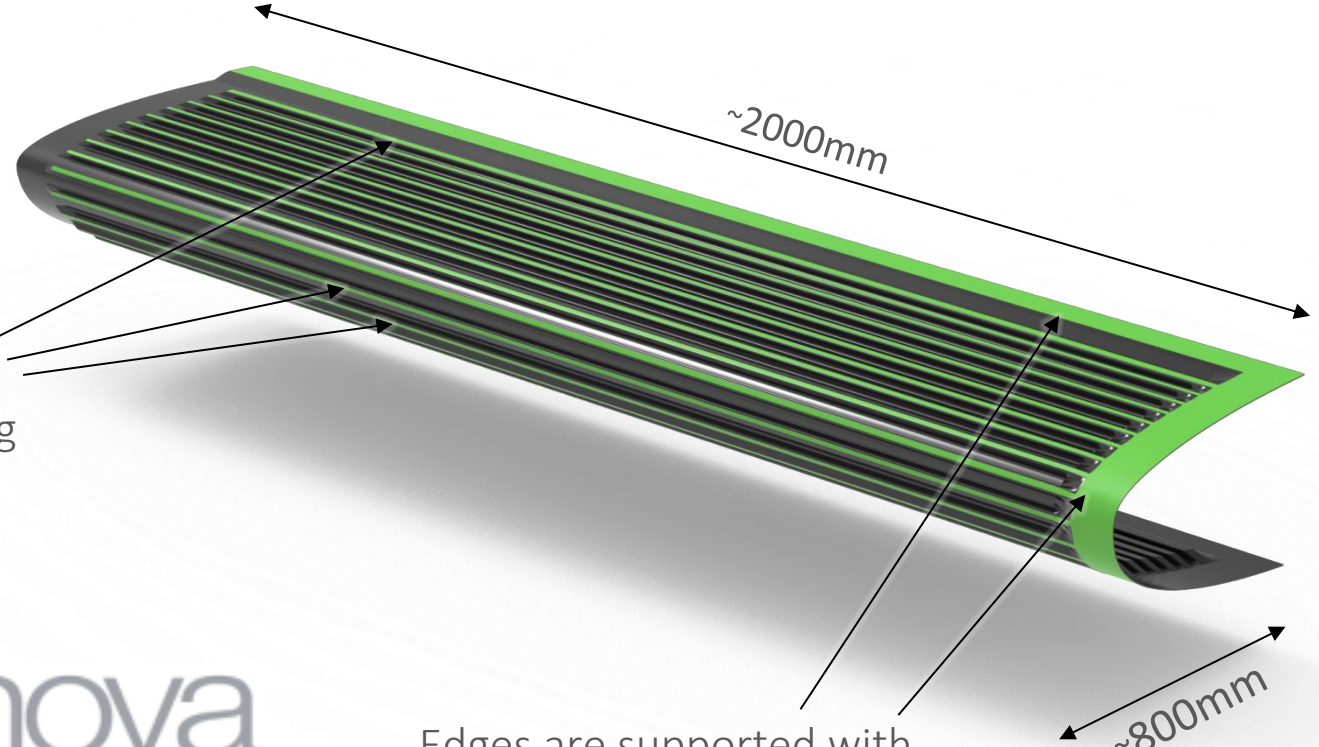
Manufacturing of a Small Scale Demonstrator

Surface Toughening Feasibility Demonstrator
testing under thermal environments



Design demonstrator
to show the Surface Toughening in Structure

Transfer to an industrial Part



Stringer are supported
with Surface Toughening

AERnnova

Edges are supported with
Surface Toughening

Results of industrial Application

- Application takes longer than expected for a curved geometry >>1h
- Misalignment due to the too flexible ST-strips (fixed)
- After curing, the PVDF shrinks and does not have a smooth surface
- No misalignment by the resin of infusion process
- Good adhesion to the CFRP
- First trial successful
- Easy application for worker by an illustrated manual

→Successful demonstration

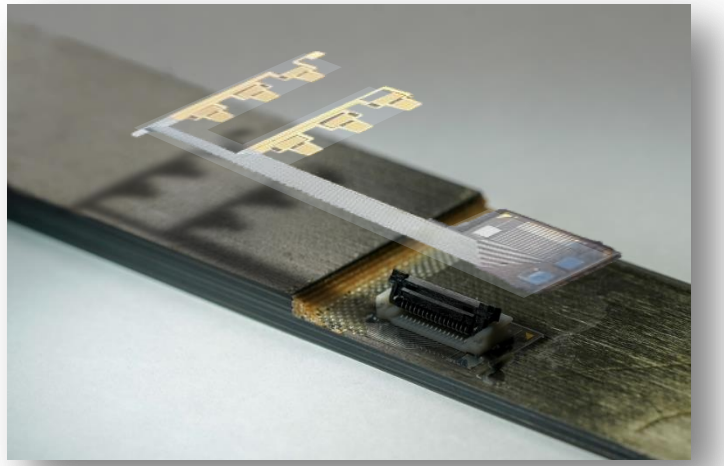
Conclusion and Outlook

Surface Toughening…

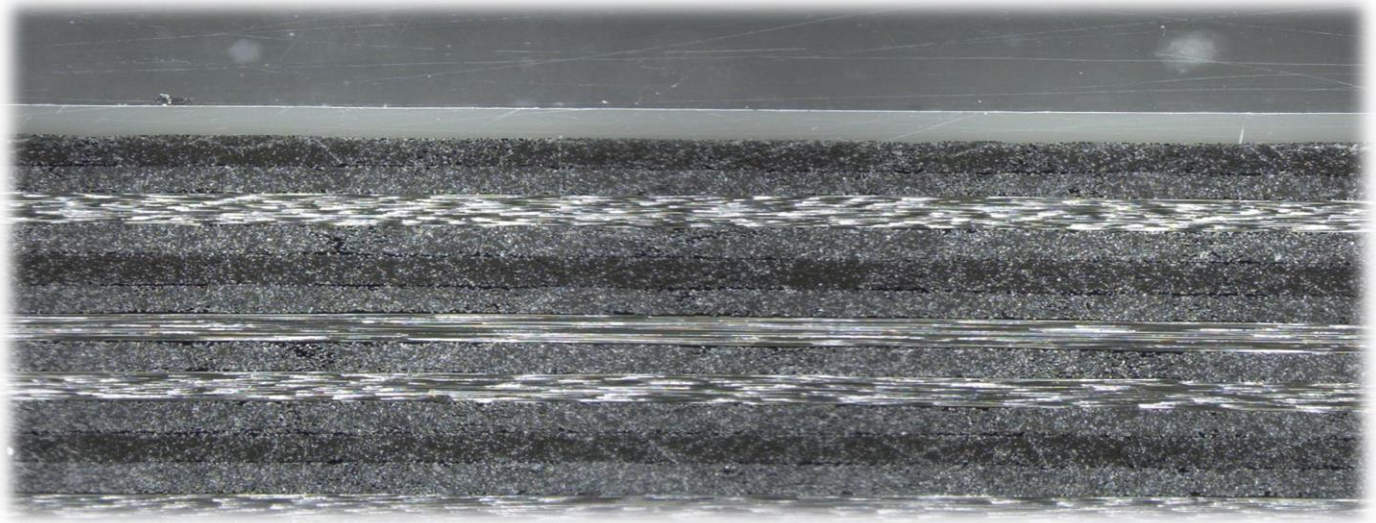
- …was presented with **good benefits for the joint strength** (SLS) and the **fatigue strength** (CLS) of bonded joints
- …was proved in a **prepreg** and **infusion system** successfully
- … is **easy to apply** and does not change the manufacturing process
- … is a **cheap technique** to reduce stress concentrations in bondline
- …was **successful demonstrated** in an industrial application

Outlook

- Identification of low temperature influence for the ductile thermoplastic material
- Identify more materials: PEI, PES, PA6, PEEK…
- Integration of a sensor to Surface Toughening for bondline monitoring



Thank You!



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Literature

- [1] T. Pe, F. Thielecke **Methodik zur Leistungsabschätzung von HLFC-Absaugsystemen im Flugzeugvorentwurf** (2010) Deutscher Luft- und Raumfahrtkongress
- [2] T. Löbel **The Hybrid Bondline: A Novel Disbond-Stopping Design for Adhesivly Bonded Composite Joints** (2016) German Aerospace Center
- [3] Loctite **Structural Adhesives Aerospace Product Selector Guide** http://www.ntkinternational.com/pdf/361151_ASA13026_structural_RW_06.pdf (2018) Henkel
- [4] Kynar **KYNAR® 740 PVDF natural** https://www.ensingerplastics.com/en-us/shapes/products/kynar-740-pvdf-natural (2018) Ensinger